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The Air Force Health Study

An Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides

Mortality Update - 1994

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The Office of Public Affairs has reviewed this technical report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of the Air Force Health study is to determine whether those individuals involved in the spraying of herbicides in Vietnam during the Ranch Hand operation have experienced any adverse health effects as a result of their participation in that program. The study is designed to evaluate both the mortality (death) and morbidity (disease) in these individuals over a 20-year period beginning in 1982.

The Baseline Mortality Report was released in June 1983, the Baseline Morbidity Report in february 1984. Follow-up mortality reports were released in 1984, 1985, 1986, 1989, and 1991. This study has not demonstrated health effects which can be conclusively attributed to herbicide or dioxin exposure.

In summary, the overall all-cause mortality experience of the Ranch Hands was not different from that expected. As of 31 December 1992, 111 (8.8%) of the 1261 Ranch hands have died; the expected number of deaths is 111.47. The observed and expected number of deaths among all Ranch Hands were not significantly different for accidental deaths, suicides and deaths caused by malignant neoplasms and circulatory system diseases. However, there were significantly increased numbers of Ranch Hand deaths due to digestive diseases and, to nonflying enlisted Ranch Hands, circulatory diseases.

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EXECUTIVE SUMMARY

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1992 found no statistically significant differences between the observed and expected number of deaths due to all causes (SMR=1.00, 95% CI 0.82-1.19, p=0.98). The adjusted all-cause death rates for Ranch Hands and Comparisons were identical (3.26 deaths per 1000 person-years). Furthermore, the observed number of deaths was not statistically different from the expected number in any of the four subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses revealed no overall significant differences between the observed and expected numbers of deaths for accidental deaths (SMR=1.14), suicides (SMR=0.70), homicides (SMR=1.21), deaths due to infectious or parasitic diseases (SMR=1.77), deaths due to malignant neoplasm (SMR=0.87), endocrine disease (SMR=1.01) or deaths due to circulatory disease (SMR=1.05). However, there was a significant excess due to circulatory system diseases among nonflying enlisted personnel (SMR=1.60, 95% CI 1.05-2.35, p=0.03). This excess was noted in the last report. The number of these deaths has increased from 22 to 24 and the SMR has increased slightly from 1.57 to 1.60 since the last report.

There was a significant excess of Ranch Hand deaths caused by diseases of the digestive system (SMR=2.07, 95% CI 1.01-3.79, p=0.05). The number of such deaths has remained at nine since 1989. This excess of Ranch Hand deaths has been noted in the last two reports. A borderline significant excess of deaths caused by diseases of the digestive system was found among Ranch Hand flying officers (SMR=2.79, 95% CI 0.89-6.74, p=0.07), although there were only four deaths in this stratum.

There was no significant increase in all Ranch Hand deaths due to ill-defined or unknown causes, however, the number of such deaths was significantly elevated among Ranch Hand flying enlisted personnel (SMR=6.11, 95% CI 1.02-20.17, p=0.05) for which the observed number of deaths is 2 and the expected number is 0.33. This excess was noted in the last report.

Analysis of survival status versus current dioxin levels found no significant difference between mean dioxin levels among the 968 living and 20 dead Ranch Hands with dioxin results. Survival time was also not significantly associated with dioxin levels in Ranch Hands.

In summary, the overall all-cause mortality experience of the Ranch Hands was not different from that expected. As of 31 December 1992, 111 (8.8%) of the 1261 Ranch Hands have died; the expected number of deaths is 111.47. The observed and expected numbers of deaths among all Ranch Hands were not significantly different for accidental deaths, suicides and

deaths caused by malignant neoplasms and circulatory system diseases. However, there were significantly increased numbers of Ranch Hand deaths due to digestive diseases and, in nonflying enlisted Ranch Hands, circulatory system diseases. The number of Ranch Hand deaths due to ill-defined or unknown causes was significantly increased among flying enlisted personnel. These increases have been noted in previous reports and are, as yet, unexplained.

1. INTRODUCTION

This report updates the findings of prior Air Force Health Study mortality reports released in 1983 [1], 1984 [2], 1985 [3], 1986 [4], 1989 [5], 1991 [6] and 1993 [7]. The reader is referred to the baseline report [1] for information regarding the study design and the mortality determination process.

This report contrasts cumulative Ranch Hand mortality through 31 December 1992 (verified as of April 1994) with that expected based on the mortality experience of the Comparison population of 19,080 Air Force veterans who flew or serviced C-130 cargo aircraft in Southeast Asia (SEA) during the same calendar period that the Ranch Hand unit was active in Vietnam (1962-1971).

In the hypothetical case that the Ranch Hand mortality experience is the same as that of the Comparison population, about 5% of the many statistical analyses shown in this report should be expected to produce p-values less than 0.05. The observation of significant results due to multiple testing on the same data, even when there is no group difference, is known as the multiple testing artifact and is common to all large studies with many dependent variables. Hence, each significant result is assessed for consistency with known exposure differences between subgroups of Ranch Hands based on rank and occupation. Nonflying enlisted personnel have higher current dioxin levels than officers and flying enlisted personnel have intermediate levels [8].

Table 1 shows summary counts, person-years and death rates by group (Ranch Hand, Comparison). A person-year is the length of time lived by one person in one year. Persons surviving to the time of data analysis contribute the time, in years, between the dates of entry into follow-up and the date of data analysis. Persons known to have died before the date of data analysis contribute the time, in years, between the dates of entry into follow-up and death. In this study, the date of entry into follow-up is the date of the start of duty in SEA. The date of data analysis is 31 December 1992. All analyses are based on regression analysis of the Standardized Mortality Ratio (SMR), the ratio of the observed to the expected number of deaths [9]. P-values and confidence intervals for the SMR were computed based on a Poisson model [10]. Except when otherwise noted, all death rates (per 1,000 person years), expected deaths and SMR's are adjusted for year of birth, age, rank (officer, enlisted) and military occupation (flyer, nonflyer).

2. ALL CAUSE MORTALITY

Summary mortality statistics for both populations are given in Table 1. In Table 1 and throughout this report, "flying officers" refers to pilots and navigators. "Officers" are flying officers and nonflying officers. "Flying enlisted personnel" are enlisted flight engineers. "Nonflying enlisted personnel" are enlisted ground personnel. Table 1 gives the number at risk, number dead, number of person-years and an adjusted death rate. Each adjusted rate [11] is the product of the Comparison death rate and the adjusted SMR given in Table 3. The result is then multiplied by 1,000 to give a death rate per 1,000 person-years.

Table 1

Summary Counts and Adjusted Death Rates
by Rank and Occupation, All Causes

	Ranch Hand				Comparison			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Flying Officers	441	36	10774	3.37	5242	454	129326	3.51
Flying Enlisted	207	20	5073	3.20	2829	293	68779	4.26
All Flyers	648	56	15846	3.28	8071	747	198106	3.77
Nonflying Officers	26	2	634	2.72	284	23	7181	3.20
Nonflying Enlisted	587	53	14311	3.41	10725	775	268149	2.89
All Nonflyers	613	55	14945	3.36	11009	798	275330	2.90
All Officers	467	38	11407	3.32	5526	4771	136508	3.49
All Enlisted	794	73	19384	3.23	13554	1068	336928	3.17
All Personnel	1261	111	30791	3.26	19080	1545	473435	3.26

*per 1000 person-years

Unadjusted occupation and race-specific mortality is summarized in Table 2. Some Ranch Hand death rates in Table 2 appear unusually high. For example, the Ranch Hand death rate among Black enlisted flight engineers is 11.33 deaths per 1,000 person-years and the corresponding rate for all Comparison deaths in this stratum is 5.41 deaths per 1,000 person-years. The four Ranch Hand deaths in this stratum have occurred since 1980. One of the four deaths was a suicide, one was accidental, one was due to a digestive system disease and one was due to ill-defined causes. An adjusted analysis shows that this increase is not statistically significant (SMR=1.8, 95% CI 0.58-4.38, p=0.25). In general, a death rate based on only a few deaths is not a reliable measure of mortality experience because one additional death can produce large changes in the death rate and the SMR.

Table 2

Unadjusted Occupation and Race Specific Cumulative All-cause Mortality

a) Nonblack Personnel

	Ranch Hand				Comparison			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Pilots	351	28	8560	3.27	3417	326	83988	3.88
Navigators	82	8	2021	3.96	1773	127	43993	2.89
Nonflying Officers	25	2	610	3.28	280	23	7081	3.25
Flying Enlisted	192	16	4720	3.39	2606	264	63418	4.16
Nonflying Enlisted	534	48	13021	3.69	9689	680	242645	2.80
Total	1184	102	28932	3.53	17765	1420	441125	3.22

Table 2 (continued)

b) Black Personnel

Stratum	Ranch Hand At Risk	Dead	Person Years	Rate*	Comparison At Risk	Dead	Person Years	Rate*
Pilots	6	0	145	0.00	20	1	509	1.96
Navigators	2	0	48	0.00	32	0	836	0.00
Nonflying Officers	1	0	24	0.00	4	0	100	0.00
Flying Enlisted	15	4	353	11.33	223	29	5361	5.41
Nonflying Enlisted	53	5	1291	3.87	1036	95	25504	3.72
Total	77	9	1859	4.84	1315	125	32310	3.87

c) All Personnel

Stratum	Ranch Hand At Risk	Dead	Person Years	Rate*	Comparison At Risk	Dead	Person Years	Rate*
Pilots	357	28	8705	3.22	3437	327	84498	3.87
Navigators	84	8	2069	3.87	1805	127	44829	2.83
Nonflying Officers	26	2	634	3.15	284	23	7181	3.20
Flying Enlisted	207	20	5073	3.94	2829	293	68779	4.26
Nonflying Enlisted	587	53	14311	3.70	10725	775	268149	2.89
Total	1261	111	30791	3.60	19080	1545	473435	3.26

*per 1000 person-years

Survival analyses were carried out to assess Ranch Hand all-cause mortality relative to the Comparison population. All analyses were adjusted for rank (officer, enlisted), occupation (flyer, nonflyer) and date of birth and age in 5-year intervals. The results are shown in Table 3. The expected numbers of deaths in Table 3 are sums of expected numbers of deaths within 5-year intervals of year of birth.

Table 3

Adjusted All-cause Standardized Mortality Ratios
by Rank and Military Occupation Among Ranch Hands

Stratum	Dead	Expected Deaths	SMR	95% C.I.	P-value
Flying Officers	36	37.55	0.96	0.68-1.31	0.82
Nonflying Officers	2	2.37	0.85	0.14-2.79	0.90
All Officers	38	39.92	0.95	0.68-1.29	0.78
Flying Enlisted	20	26.68	0.75	0.47-1.14	0.19
Nonflying Enlisted	53	44.87	1.18	0.89-1.53	0.23
All Enlisted	73	71.56	1.02	0.81-1.32	0.85
All Flying Personnel	56	64.24	0.87	0.66-1.12	0.30
All Nonflying Personnel	55	47.24	1.16	0.89-1.50	0.26
All Ranch Hands	111	111.47	1.00	0.82-1.19	0.98

There are no significant differences between the observed and expected number of deaths from all causes in any stratum. The overall adjusted SMR for all Ranch Hands for all causes of death is 1.00, 95% CI 0.82-1.19, p=0.98, because the expected number of deaths (111.47) is very close to the observed number of deaths (111).

One degree of freedom chi-square tests for trend [9] were applied to all strata to assess the significance of trends in the SMR since 1986. These analyses were carried out twice, first with each of the years 1986 through 1992 separately contributing to the test statistic and again with 1986 through 1989 collapsed to a single stratum and 1990 through 1992 collapsed to a second stratum. All analyses are conditioned on survival to 1 January 1986 and due to sparseness were not adjusted for date of birth. These tests are two-tailed and therefore would detect upward or downward trends in the SMR. The results are shown in Table 4.

Table 4

All-cause Ranch Hand Mortality
Seven-year Trend Analysis

Flying Officers

One Sample Chi-square(single year) =7.76 P =0.01
One Sample Chi-square(86-89,90-92) =6.19 P =0.01

Year	Dead	Rate*	Expected Deaths	SMR
1986	5	11.84	1.79	2.80
1987	5	11.94	2.55	1.96
1988	5	12.11	2.69	1.86
1989	2	4.88	1.76	1.13
1990	2	4.91	2.44	0.82
1991	0	0.00	2.02	0.00
1992	1	2.47	2.03	0.00

Enlisted Flyers

One Sample Chi-square(single year) =0.23 P =0.63
One Sample Chi-square(86-89,90-92) =1.49 P =0.22

Year	Dead	Rate*	Expected Deaths	SMR
1986	1	5.08	1.26	0.79
1987	1	5.11	0.89	1.12
1988	0	0.00	1.42	0.00
1989	1	5.13	0.82	1.21
1990	3	15.56	0.97	3.10
1991	3	15.78	1.25	2.39
1992	1	5.35	2.27	0.44

Table 4 (continued)

All Flyers

One Sample Chi-square(single year) =3.79 P =0.05
One Sample Chi-square(86-89,90-92) =1.85 P =0.17

Year	Dead	Rate*	Expected Deaths	SMR
1986	6	9.70	3.09	1.94
1987	6	9.77	3.41	1.76
1988	5	8.22	4.12	1.21
1989	3	4.96	2.59	1.16
1990	5	8.33	3.39	1.48
1991	3	5.03	3.30	0.91
1992	2	3.38	4.43	0.45

Nonflying Officers

One Sample Chi-square(single year) =0.18 P =0.67
One Sample Chi-square(86-89,90-92) =0.26 P =0.61

Year	Dead	Rate*	Expected Deaths	SMR
1986	0	0.00	0.18	0.00
1987	0	0.00	0.37	0.00
1988	0	0.00	0.37	0.00
1989	1	40.54	0.09	10.73
1990	0	0.00	0.09	0.00
1991	0	0.00	0.00	0.00
1992	0	0.00	0.18	0.00

Nonflying Enlisted Personnel

One Sample Chi-square(single year) =0.45 P =0.50
One Sample Chi-square(86-89,90-92) =0.14 P =0.70

Year	Dead	Rate*	Expected Deaths	SMR
1986	3	5.42	1.89	1.59
1987	2	3.63	2.37	0.84
1988	6	10.96	2.69	2.23
1989	1	1.84	2.58	0.39
1990	4	7.38	3.01	1.33
1991	2	3.71	2.85	0.70
1992	3	5.60	2.58	1.16

Table 4 (continued)

All Nonflyers

One Sample Chi-square(single year) =0.33 P =0.56
One Sample Chi-square(86-89,90-92) =0.22 P =0.64

Year	Dead	Rate*	Expected Deaths	SMR
1986	3	5.19	2.03	1.48
1987	2	3.47	2.63	0.76
1988	6	10.48	2.96	2.03
1989	2	3.52	2.68	0.75
1990	4	7.07	3.12	1.28
1991	2	3.56	2.90	0.69
1992	3	5.36	2.73	1.10

All Officers

One Sample Chi-square(single year) =6.67 P =0.01
One Sample Chi-square(86-89,90-92) =6.17 P =0.01

Year	Dead	Rate*	Expected Deaths	SMR
1986	5	11.18	1.97	2.54
1987	5	11.27	2.90	1.73
1988	5	11.42	3.05	1.64
1989	3	6.91	1.86	1.61
1990	2	4.64	2.53	0.79
1991	0	0.00	2.03	0.00
1992	1	2.33	2.21	0.45

All Enlisted Personnel

One Sample Chi-square(single year) =0.04 P =0.83
One Sample Chi-square(86-89,90-92) =0.17 P =0.68

Year	Dead	Rate*	Expected Deaths	SMR
1986	4	5.33	3.02	1.32
1987	3	4.02	3.25	0.92
1988	6	8.08	4.00	1.50
1989	2	2.71	3.42	0.58
1990	7	9.52	4.00	1.75
1991	5	6.86	4.05	1.24
1992	4	5.54	4.56	0.88

Table 4 (continued)

All Ranch Hands

One Sample Chi-square(single year) =3.60 P =0.06
One Sample Chi-square(86-89,90-92) =1.81 P =0.18

Year	Dead	Rate*	Expected Deaths	SMR
1986	9	7.52	4.95	1.82
1987	8	6.72	5.93	1.35
1988	11	9.32	6.89	1.60
1989	5	4.26	5.32	0.94
1990	9	7.72	6.49	1.39
1991	5	4.32	6.15	0.81
1992	5	4.34	6.88	0.73

*per 1000 person-years

Table 4 shows a highly significant downward trend among flying officers (p=0.01) caused by relatively low death rates after 1988. The strength of this seven-year trend is reflected among all officers (p=0.01), and to a lesser degree, all flyers (p=0.05) and all Ranch Hands (p=0.06).

A lexis diagram [11] for Ranch Hand flying officers is shown in Figure 1. Follow-up time is indicated for each living subject with a straight line beginning at his age at the beginning of his first qualifying tour of duty in SEA and ending with his age at 31 December 1992. Follow-up lines for deceased subjects end with a square at the subject's age at death and date of death. The corresponding diagram without the follow-up lines is shown in Figure 2. Lexis diagrams for nonflying officers, flying enlisted and nonflying enlisted personnel, without follow-up lines, are shown in Figures 3 through 5.

Lexis diagrams provide another view of the data that permits a visual assessment of mortality clustering with respect to age and calendar time. A strong latency effect, for example, might be revealed by a cluster of deaths approximately 20 years after entry into follow-up. No such clusters are apparent in these data.

Figure 1
Lexis Diagram
Ranch Hand Flying Officers

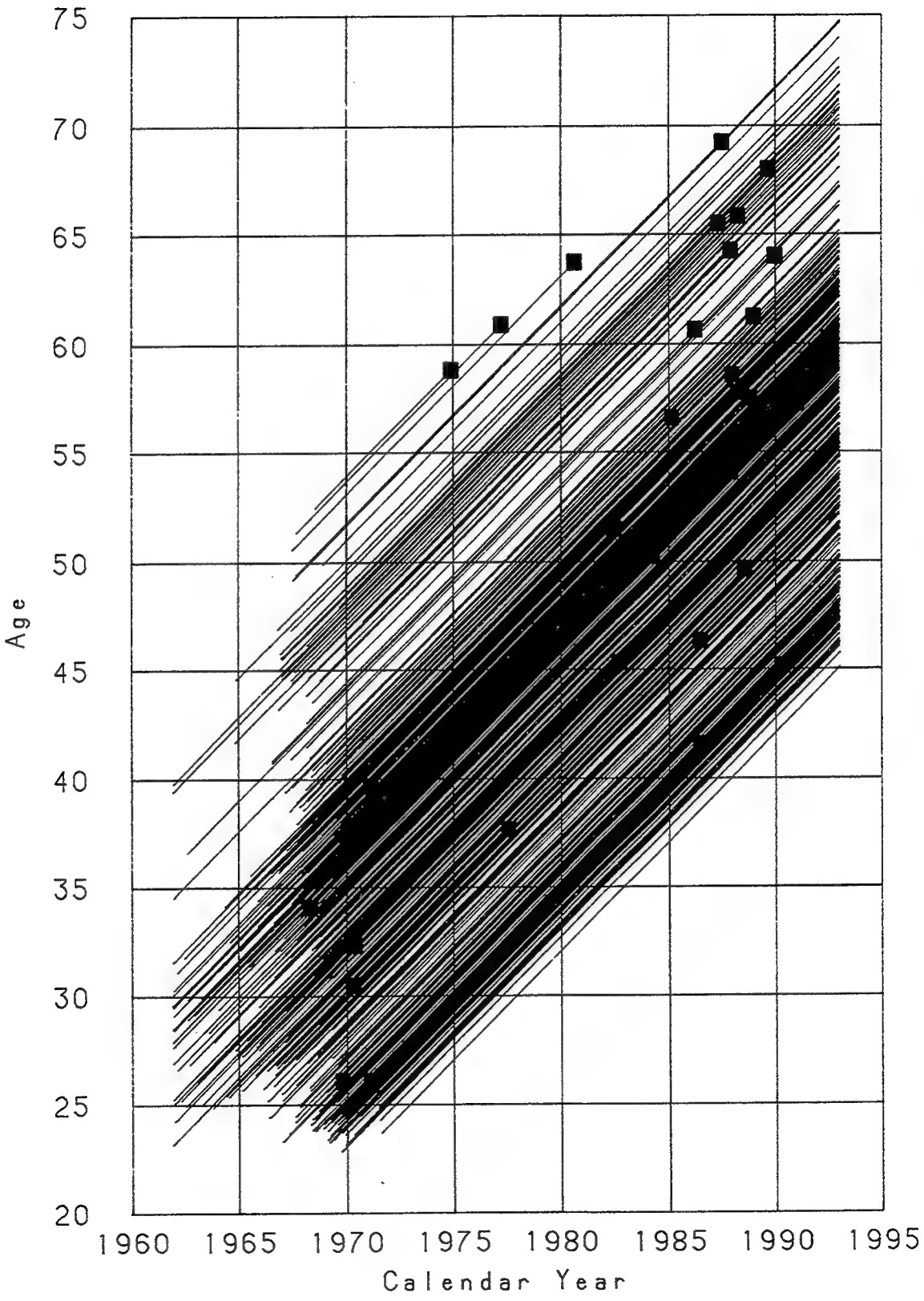


Figure 2
Lexis Diagram
Ranch Hand Flying Officers

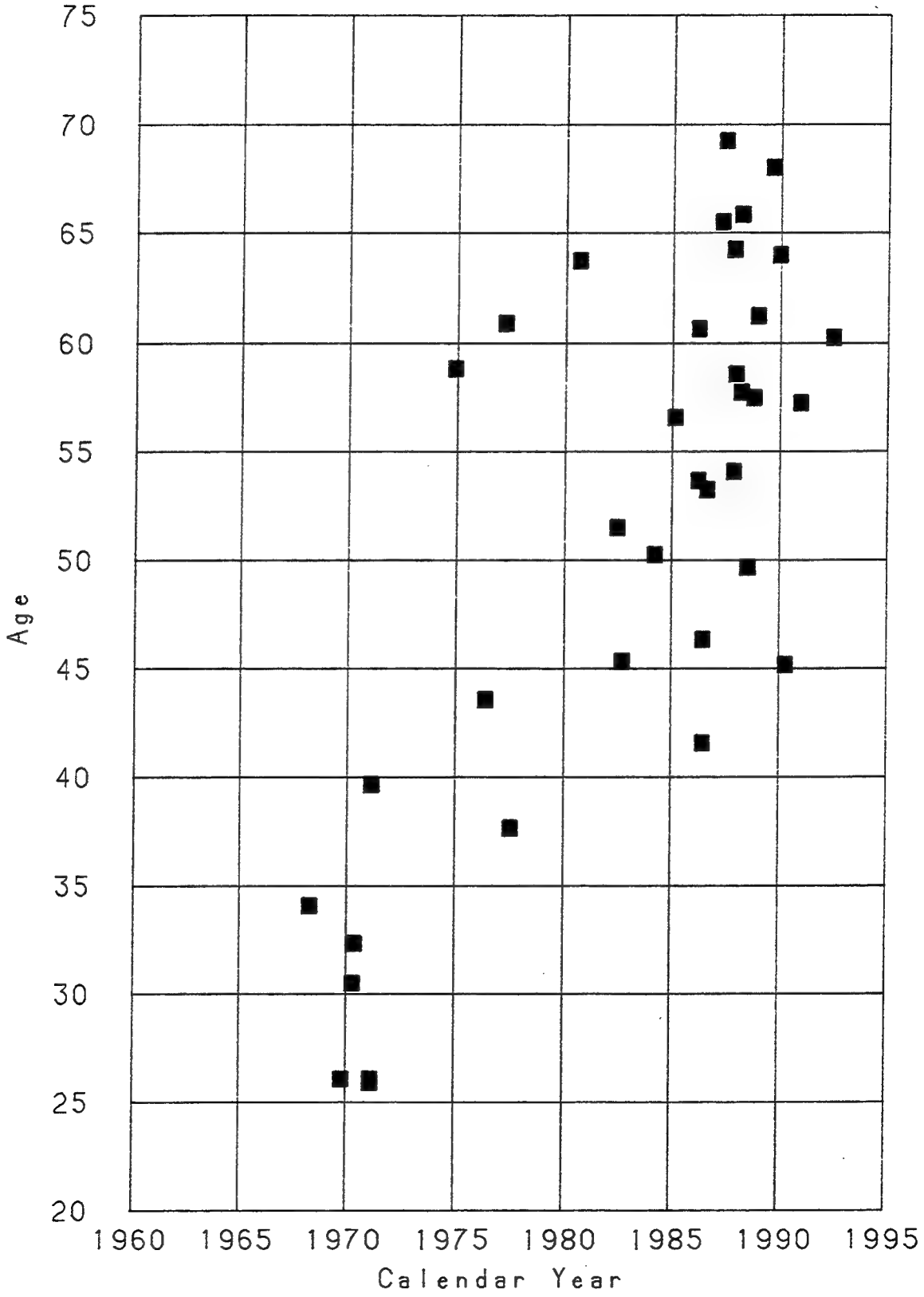


Figure 3
Lexis Diagram
Ranch Hand Nonflying Officers

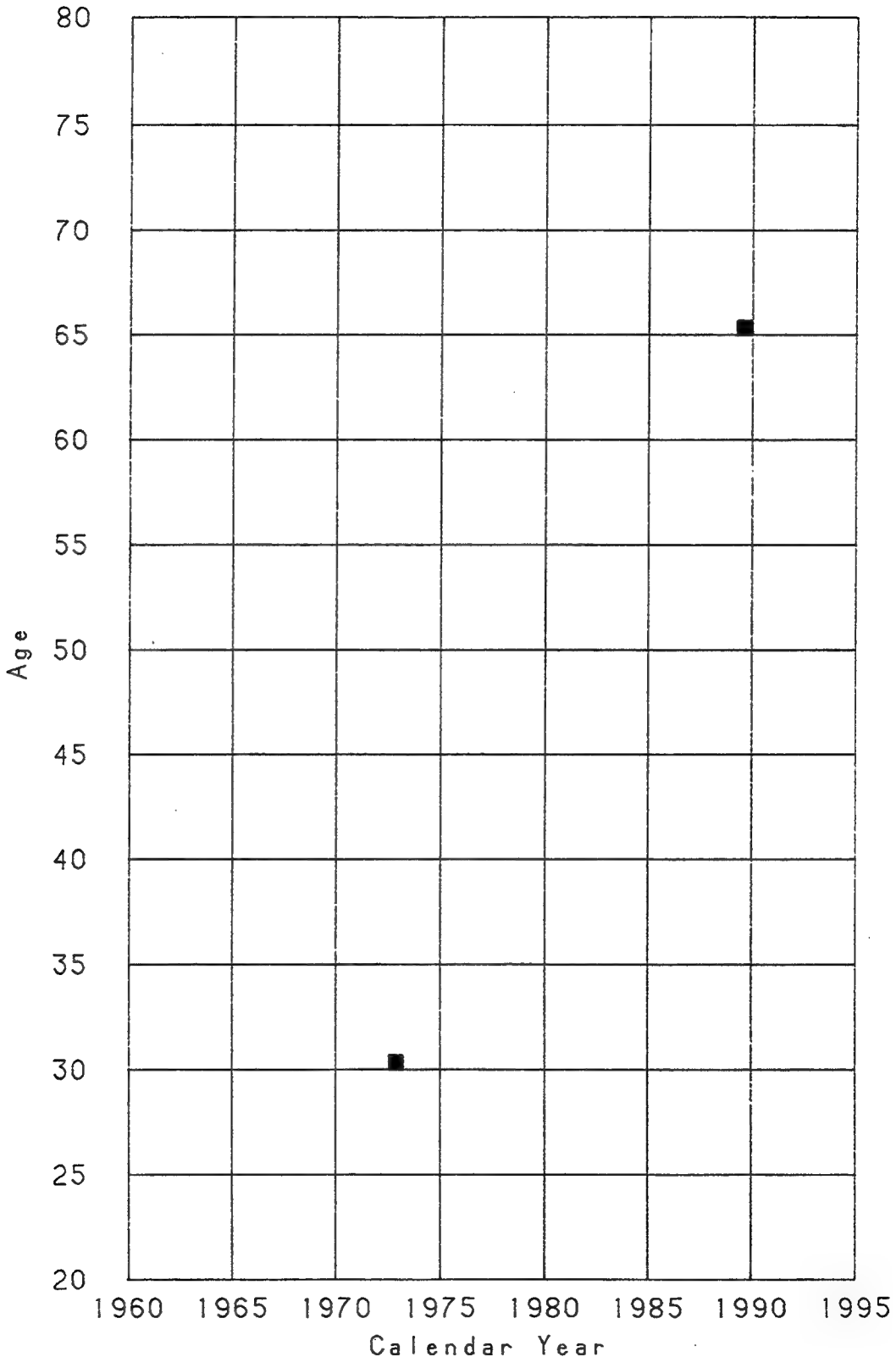


Figure 4
Lexis Diagram
Ranch Hand Flying Enlisted

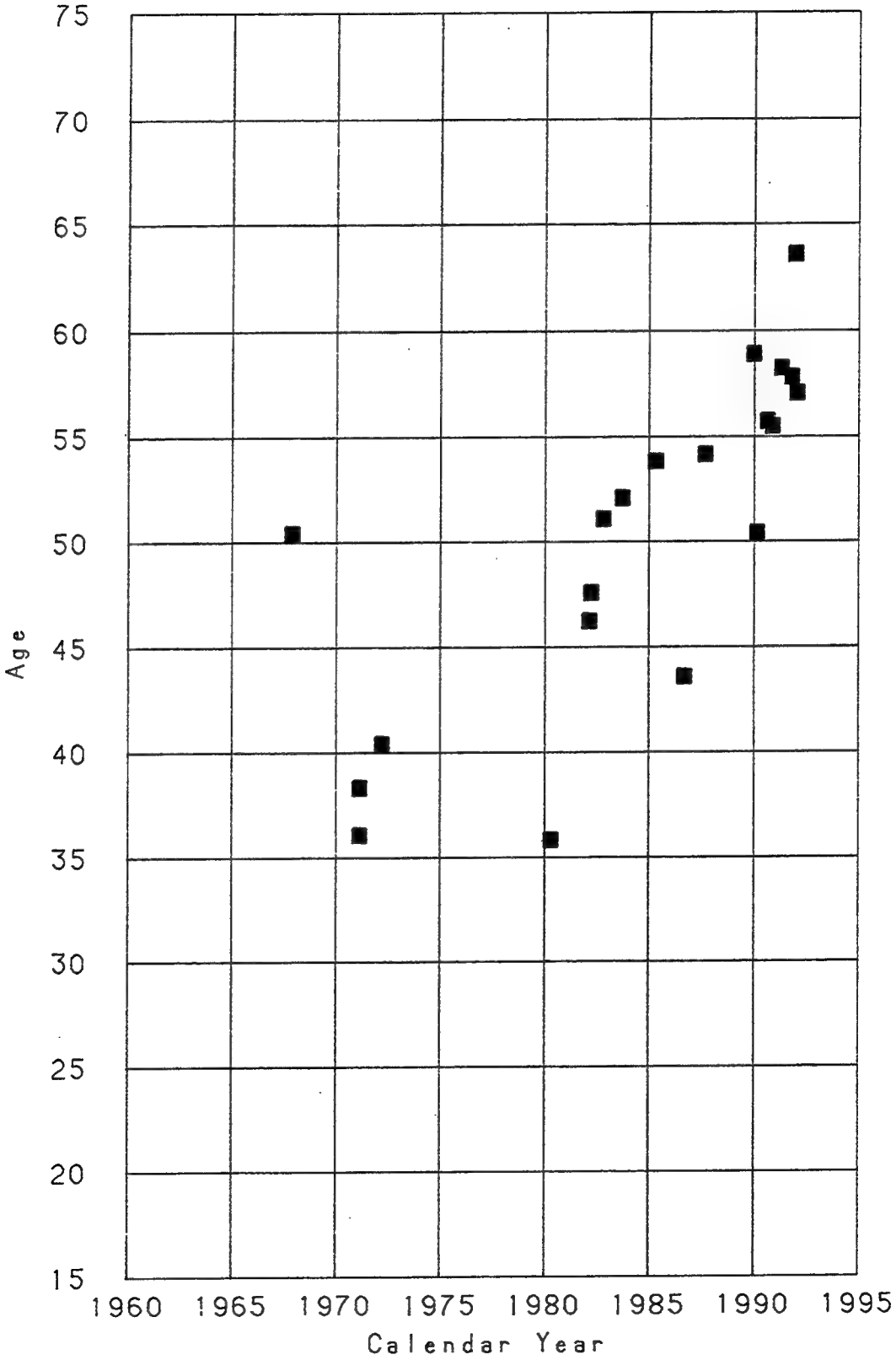
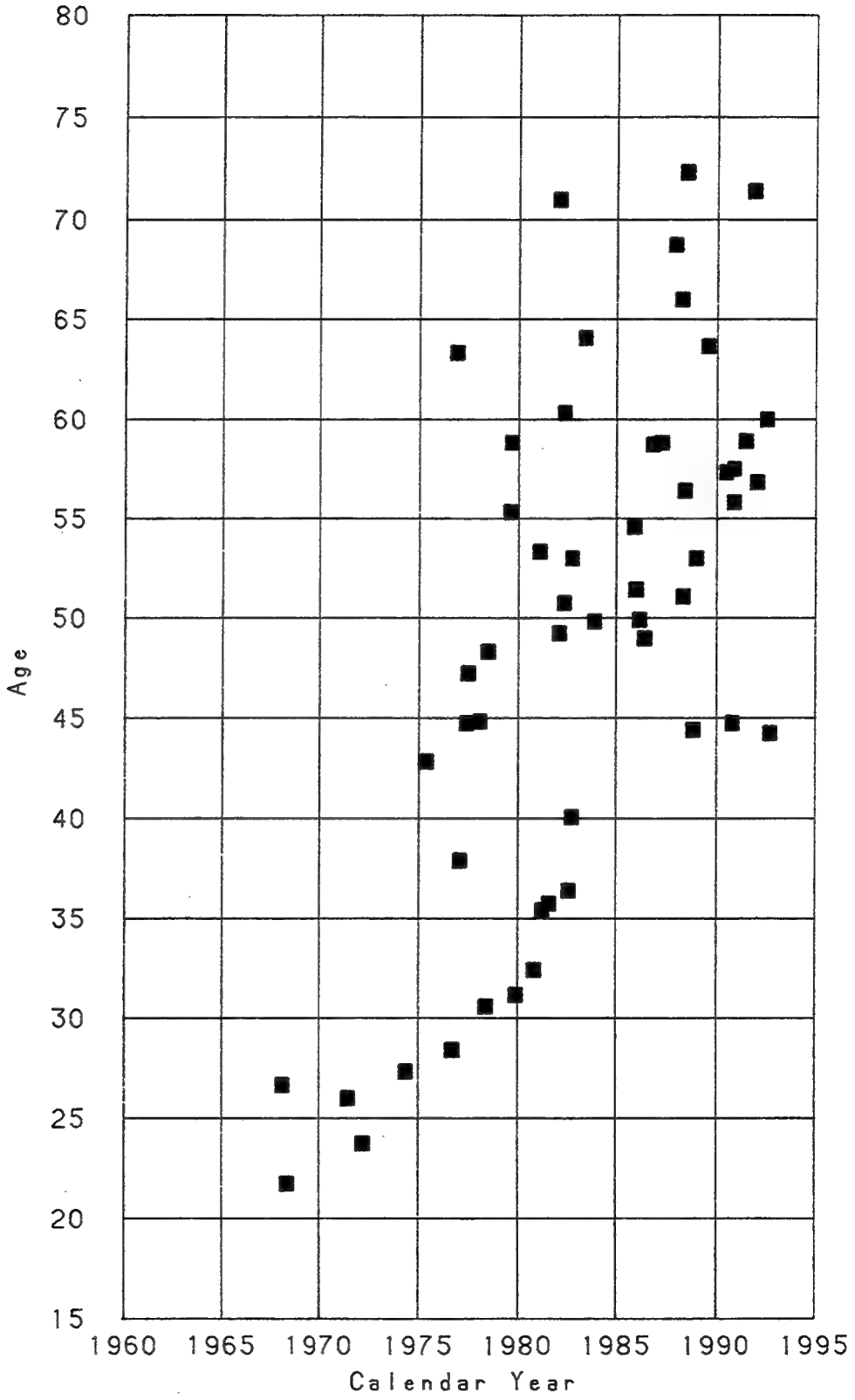


Figure 5
Lexis Diagram
Ranch Hand Nonflying Enlisted



3. CAUSE-SPECIFIC MORTALITY

Observed and adjusted expected Ranch Hand deaths by specific cause and stratum of rank and occupation are summarized in Table 5.

Table 5

Adjusted Cause-specific Ranch Hand Mortality by Rank and Occupation

Cause	Stratum	Dead	Expected Deaths	SMR	95% C.I.	P-value
Accident	Flying Officer	10	8.22	1.22	0.62-2.17	0.52
	Flying Enlisted	4	5.43	0.74	0.23-1.78	0.58
	Nonflying Officer	0	0.10	0.00		
	Nonflying Enlisted	11	8.20	1.34	0.71-2.33	0.33
	All Ranch Hands	25	21.95	1.14	0.75-1.66	0.50
Suicide	Flying Officer	0	1.43	0.00		
	Flying Enlisted	2	1.56	1.28	0.21-4.23	0.67
	Nonflying Officer	1	0.12	8.64	0.43-42.60	0.12
	Nonflying Enlisted	1	2.63	0.38	0.02-1.87	0.33
	All Ranch Hands	4	5.75	0.70	0.22-1.68	0.50
Homicide	Flying Officer	0	0.28	0.00		
	Flying Enlisted	0	0.42	0.00		
	Nonflying Officer	0	0.00			
	Nonflying Enlisted	2	0.95	2.11	0.35-6.96	0.32
	All Ranch Hands	2	1.65	1.21	0.20-4.00	0.72
Infectious -Parasitic	Flying Officer	1	0.60	1.67	0.08-8.23	0.57
	Flying Enlisted	0	0.10	0.00		
	Nonflying Officer	0	0.00			
	Nonflying Enlisted	1	0.43	2.33	0.12-11.51	0.42
	All Ranch Hands	2	1.13	1.77	0.30-5.85	0.42
Malignant Neoplasm	Flying Officer	8	10.65	0.75	0.35-1.43	0.43
	Flying Enlisted	7	7.24	0.97	0.42-1.91	0.98
	Nonflying Officer	1	0.58	1.73	0.09-8.51	0.56
	Nonflying Enlisted	10	11.52	0.87	0.44-1.55	0.69
	All Ranch Hands	26	29.99	0.87	0.58-1.25	0.48
Endocrine Disease	Flying Officer	0	0.25	0.00		
	Flying Enlisted	0	0.21	0.00		
	Nonflying Officer	0	0.00			
	Nonflying Enlisted	1	0.53	1.89	0.09-9.30	0.51
	All Ranch Hands	1	0.99	1.01	0.05-5.00	0.89

Table 5 (continued)

Cause	Stratum	Dead	Expected Deaths	SMR	95% C.I.	P-value
Circulatory Disease	Flying Officer	12	12.24	0.98	0.53-1.67	0.98
	Flying Enlisted	3	8.60	0.35	0.09-0.95	0.04
	Nonflying Officer	0	1.36	0.00		
	Nonflying Enlisted	24	14.96	1.60	1.05-2.35	0.03
	All Ranch Hands	39	37.15	1.05	0.76-1.42	0.74
Digestive Disease	Flying Officer	4	1.43	2.79	0.89-6.74	0.07
	Flying Enlisted	2	1.33	1.51	0.25-4.98	0.53
	Nonflying Officer	0	0.10	0.00		
	Nonflying Enlisted	3	1.50	2.00	0.51-5.46	0.26
	All Ranch Hands	9	4.36	2.07	1.01-3.79	0.05
Ill-Defined Unknown	Flying Officer	1	0.38	2.65	0.13-13.05	0.37
	Flying Enlisted	2	0.33	6.11	1.02-20.17	0.05
	Nonflying Officer	0	0.00			
	Nonflying Enlisted	0	0.78	0.00		
	All Ranch Hands	3	1.49	2.02	0.51-5.50	0.25

There are no overall or within-stratum significant differences between observed and expected numbers of deaths due to accidents, suicides, homicides, infectious or parasitic diseases, malignant neoplasms or endocrine diseases (Table 5). There is a significantly increased number of deaths caused by diseases of the circulatory system among Ranch Hand nonflying enlisted personnel (SMR=1.60, 95% CI 1.05-2.35, p=0.03). By contrast, the 3 flying enlisted deaths are significantly less than the 8.6 expected deaths (SMR=0.35, 95% CI 0.09-0.95, p=0.04). An increased number of deaths due to digestive diseases was found in all Ranch Hands (SMR=2.07, 95% CI 1.01-3.79, p=0.05), with a borderline significant excess among Ranch Hand flying officers (SMR=2.79, 95% CI 0.89-6.74, p=0.07). There was no significant increase in all Ranch Hand deaths due to ill-defined or unknown causes, but the number of such deaths was significantly elevated among Ranch Hand flying enlisted personnel (SMR=6.11, 95% CI 1.02-20.17, p=0.05), although the number of deaths in this stratum is small (the observed number is 2 and the expected number is 0.33).

Table 6 shows cumulative site-specific malignant neoplasm mortality among Ranch Hands.

Table 6

Site-specific Malignant Neoplasm Ranch Hand Mortality

ICD Code	Site	Dead	Expected Deaths
140-149	Lip,Oral Cavity and Pharynx		
140.9	Lip, Unspecified	0	0.092
141.9	Tongue, Unspecified	0	0.193
144.9	Floor of Mouth, Unspecified	0	0.182
145.3	Soft Palate	0	0.092
145.9	Mouth, Unspecified	0	0.156
146.0	Tonsil	0	0.097
147.9	Nasopharynx, Unspecified	0	0.092
148.1	Pyriform Sinus	0	0.157
149.0	Pharynx, Unspecified	0	0.184
150-159	Digestive Organs and Peritoneum		
150.3	Oesophagus, Upper Third	0	0.052
150.5	Oesophagus, Lower Third	0	0.064
150.9	Oesophagus, Unspecified	1	0.990
151.9	Stomach, Unspecified	1	0.352
153.4	Colon, Caecum	0	0.090
153.5	Colon, Appendix	0	0.140
153.9	Colon, Unspecified	1	2.379
154.0	Rectosigmoid Junction	0	0.375
154.1	Rectum	0	0.299
154.3	Anus, Unspecified	0	0.092
155.0	Liver, Primary	0	0.142
155.1	Intrahepatic Bile Ducts	0	0.148
155.2	Liver, Unspecified	1	0.000
156.0	Gall Bladder	0	0.090
157.4	Islets of Langerhans	0	0.178
157.9	Pancreas, Unspecified	1	1.049
159.0	Intestinal Tract, Unspecified	0	0.092
160-165	Respiratory and Intrathoracic Organs		
160.9	Accessory Sinus, Unspecified	0	0.052
161.1	Supraglottic	0	0.087
161.9	Larynx, Unspecified	0	0.398
162.2	Main Bronchus	0	0.064
162.3	Upper Lobe, Bronchus or Lung	0	0.152
162.4	Middle Lobe, Bronchus or Lung	0	0.065
162.9	Bronchus and Lung, Unspecified	11	11.844
163.9	Pleura, Unspecified	0	0.064
164.9	Mediastinum, Unspecified	1	0.108
170-175	Bone,Connective Tissue, Skin and Breast		
170.9	Bone and Articular Cartilage, Unsp	0	0.058
171.0	Head, Face and Neck	0	0.051
171.3	Lower Limb, Including Hip	1	0.000
171.5	Abdomen	0	0.091
171.8	Connective, Soft Tissue, Other	0	0.087
171.9	Site Unspecified	0	0.276
172.5	Skin, Trunk	0	0.065
172.9	Skin, Unspecified	0	0.614

Table 6 (continued)

ICD Code	Site	Dead	Expected Deaths
179-189	Genitourinary Organs		
185.0	Prostate	0	0.599
188.9	Bladder, Unspecified	0	0.351
189.0	Kidney, Except Pelvis	1	0.506
190-199	Other and Unspecified Sites		
191.1	Brain, Frontal Lobe	0	0.052
191.3	Parietal Lobe	0	0.058
191.4	Occipital Lobe	0	0.092
191.7	Brain Stem	0	0.116
191.9	Brain, Unspecified	1	0.905
193	Thyroid Gland	0	0.051
195.0	Head, Face and Neck	0	0.516
195.8	Other Unspecified Site	0	0.064
199.1	Other, Unspecified	3	2.365
200-208	Lymphatic and Hematopoietic Tissue		
200.0	Reticulosarcoma	0	0.091
200.1	Lymphosarcoma	0	0.088
200.8	Reticulolymphosarcoma	0	0.092
201.9	Hodgkin's Disease, Unspecified	0	0.140
202.8	Other Lymphomas	0	0.452
203.0	Multiple Myeloma	1	0.892
204.0	Acute Lymphoid Leukaemia	0	0.056
204.1	Chronic Lymphoid Leukaemia	0	0.216
204.9	Lymphoid Leukaemia, Unspecified	0	0.121
205.0	Acute Myeloid Leukaemia	0	0.445
205.1	Chronic Myeloid Leukaemia	0	0.120
205.3	Myeloid Sarcoma	0	0.087
206.0	Acute Monocytoid Leukaemia	0	0.063
207.8	Lymphosarcoma Cell Leukaemia	0	0.087
208.0	Acute Leukaemia, Unspecified	0	0.157
210-229	Benign Neoplasms		
213.0	Benign, Bone, Articular Cartilage	0	0.087
	Totals	26	30.682

The 26 Ranch Hand deaths due to malignant neoplasm do not appear to aggregate in an unusual pattern relative to that expected (Table 6).

The morphology of cumulative malignant neoplasm deaths is summarized in Table 7.

Table 7

Morphology of Ranch Hand Malignant Neoplasms

Code	Morphology	Dead	Expected Deaths
M800	Neoplasms NOS		
140-149	Lip,Oral Cavity and Pharynx	0	0.065
150-159	Digestive Organs and Peritoneum	1	2.517
160-165	Respiratory and Intrathoracic Organs	5	4.894
179-189	Genitourinary Organs	0	0.662
190-199	Other and Unspecified Sites	1	1.311
M801-M804	Epithelial Neoplasms NOS		
140-149	Lip,Oral Cavity and Pharynx	0	0.373
150-159	Digestive Organs and Peritoneum	3	1.754
160-165	Respiratory and Intrathoracic Organs	6	5.444
170-175	Bone,Connective Tissue, Skin, Breast	0	0.091
179-189	Genitourinary Organs	1	0.318
190-199	Other and Unspecified Sites	1	0.786
M805-M808	Papillary and Squamous Cell Neoplasms		
140-149	Lip,Oral Cavity and Pharynx	0	0.718
150-159	Digestive Organs and Peritoneum	0	0.299
160-165	Respiratory and Intrathoracic Organs	0	0.777
190-199	Other and Unspecified Sites	1	0.467
M814-M838	Adenomas and Adenocarcinomas		
150-159	Digestive Organs and Peritoneum	1	1.962
160-165	Respiratory and Intrathoracic Organs	0	1.462
179-189	Genitourinary Organs	1	0.436
190-199	Other and Unspecified Sites	1	0.527
M856-M858	Complex Epithelial Neoplasms		
190-199	Other and Unspecified Sites	0	0.092
M872-M879	Naevi and Melanomas		
160-165	Respiratory and Intrathoracic Organs	1	0.000
170-175	Bone,Connective Tissue, Skin, Breast	0	0.678
M880	Soft Tissue Tumors & Sarcomas NOS		
170-175	Bone,Connective Tissue, Skin, Breast	0	0.269
190-199	Other and Unspecified Sites	0	0.065
M881-M883	Fibromatous Neoplasms		
140-149	Lip,Oral Cavity and Pharynx	0	0.090
170-175	Bone,Connective Tissue, Skin, Breast	1	0.000
M885-M888	Lipomatous Neoplasms		
170-175	Bone,Connective Tissue, Skin, Breast	0	0.058
M905	Mesothelial Neoplasms		
160-165	Respiratory and Intrathoracic Organs	0	0.156
M906-M909	Germ Cell Neoplasms		
160-165	Respiratory and Intrathoracic Organs	0	0.051
190-199	Other and Unspecified Sites	0	0.058
M921-M924	Chondromatous Neoplasms		
210-229	Benign Neoplasms	0	0.087
M926	Miscellaneous Bone Tumors		
170-175	Bone,Connective Tissue, Skin, Breast	0	0.058

Table 7 (continued)

Code	Morphology	Dead	Expected Deaths
M938-M948	Gliomas		
190-199	Other and Unspecified Sites	0	0.914
M949-M952	Neuroepitheliomatous Neoplasms		
170-175	Bone,Connective Tissue, Skin, Breast	0	0.087
M959-M963	Lymphomas NOS or Diffuse		
200-208	Lymphatic and Hematopoietic Tissue	0	0.543
M964	Reticulosarcomas		
200-208	Lymphatic and Hematopoietic Tissue	0	0.179
M965-M966	Hodgkin's Disease		
200-208	Lymphatic and Hematopoietic Tissue	0	0.140
M973	Plasma Cell Tumors		
200-208	Lymphatic and Hematopoietic Tissue	1	0.892
M980	Leukaemia NOS		
200-208	Lymphatic and Hematopoietic Tissue	0	0.157
M982	Lymphoid Leukaemia		
200-208	Lymphatic and Hematopoietic Tissue	0	0.393
M985	Lymphosarcoma Cell Leukaemia		
200-208	Lymphatic and Hematopoietic Tissue	0	0.087
M986	Myeloid Leukaemia		
200-208	Lymphatic and Hematopoietic Tissue	0	0.564
M989	Monocytic Leukaemia		
200-208	Lymphatic and Hematopoietic Tissue	0	0.063
M990	Miscellaneous Leukaemia		
160-165	Respiratory and Intrathoracic Organs	0	0.051
200-208	Lymphatic and Hematopoietic Tissue	0	0.087
	Totals	26	30.682

Although the adjusted SMR for deaths due to malignant neoplasm is less than 1.0 (Table 5), there are morphologic subcategories of malignancies for which the SMR is greater than 1.0. For example, there are 11 Ranch Hand deaths from epithelial neoplasms not otherwise specified and the expected number of deaths in this category is 8.8. However, this excess is not significant (SMR=1.27, 95% CI 0.67-2.20, p=0.42).

4. MORTALITY VERSUS CURRENT DIOXIN LEVELS

Since the introduction of the dioxin assay into the morbidity component of this study, all health data has been assessed for associations with dioxin [8]. All dioxin assay results are qualified by a result comment defined in Table 8.

Table 8

Result Comment Definition

Result Comment	Definition
G	Good result
GND	Good result, below limit of detection
GNQ	Good result, below limit of quantitation
NR	No result

Dioxin results of assayed participants from the 1992 physical examination, the 1987 physical examination and the pilot study conducted in April 1987, were combined into the dioxin data base used in this report. Dioxin assays have been administered to 1005 (80%) of the total 1261 Ranch Hands. Table 9 shows a cross classification of all 1261 Ranch Hands by survival status (dead, alive), assay status (yes, no) and result comment.

Table 9

Ranch Hand Dioxin Assay Status versus Survival

		Survival Status		
Dioxin Assay	Result Comment	Alive	Dead	Total
No		168	88	256
Yes	G	958	19	977
	GND	10	1	11
	GNQ	3	2	5
	NR	11	1	12
Total		1150	111	1261

Some participants were assayed more than once and may have up to three assay results each. When a participant had multiple assay results, the earliest quantifiable result was used. First priority was given to 1987 pilot study dioxin results, second priority to results derived from serum collected at the 1987 physical examination and third priority was given to the 1992 results. The dioxin level of most (82%) of the 1005 participants with dioxin results was derived from serum collected in 1987. If a Ranch Hand had a 1992 dioxin result and did not have a 1987 dioxin result, and if the 1992 result surpassed 10 ppt, the 1992 result was extrapolated to a 1987 level because statistical analyses were based on 1987 dioxin levels. The extrapolated values were calculated using a first order decay model with a half-life of 7.1 years.

Ranch Hands with missing dioxin results (no assay or assayed with result comment NR) and nonquantifiable results (result comment GNQ) were excluded from subsequent analyses of survival versus dioxin. After these exclusions, 968 living Ranch Hands and 20 dead Ranch Hands had dioxin results. Dioxin results are lognormally distributed, hence the logarithm of dioxin was used in the analysis, with one added to the dioxin value before taking the logarithm. Univariate summaries of dioxin, expressed in parts per trillion (ppt), and its logarithm, in log(ppt), are summarized in Table 10.

Table 10

Dioxin Summary

	Dioxin		Log(dioxin+1)	
Statistic	Alive	Dead	Alive	Dead
n	968	20	968	20
Minimum	0	0	0	0
Maximum	617.8	211.0	6.4	5.4
Mean	26.6	38.9	2.7	2.9
Median	12.0	13.6	2.6	2.7
Standard Deviation	44.7	57.7	1.0	1.3

The mean values of log(dioxin+1) do not differ significantly with survival status; mean difference=0.17, 95% CI -0.28, 0.63, p=0.57.

Of the 20 deceased Ranch Hands with quantifiable dioxin results, 2 died of digestive disease, 6 died of malignant neoplasms, 10 died of circulatory diseases, 1 died of an accident and 1 committed suicide.

An accelerated failure time model for right-censored survival data was fitted to assess the relationship, if any, between survival time and the logarithm of dioxin level in Ranch Hands. In this analysis, the survival time of dead Ranch Hands is the time in years between the beginning of their tour in Vietnam and death. The survival time of living Ranch Hands is the time, in years, between 31 December 1992 and the beginning of their tour of duty in Vietnam. The analysis was unadjusted, due to the small number of dead Ranch Hands (20) with dioxin values. The dependent variable was the logarithm of survival time and the independent variable was log(dioxin+1). The results are summarized in Table 11. There is no significant association between dioxin level and survival time among Ranch Hands (p=0.28).

Table 11

Survival Time versus Dioxin in Ranch Hands

Coefficient	Chi-square	Degrees of Freedom	95% CI	P-value
-0.0299	1.16	1	-0.084, 0.025	0.28

5. CONCLUSIONS

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1992 revealed no statistically significant differences between the observed and expected number of deaths (SMR=1.00, 95% CI 0.82-1.19, p=0.98). The adjusted all-cause death rates for Ranch Hands and Comparisons were identical (3.26 deaths per 1000 person-years). Furthermore, without regard to cause, the observed and expected number of deaths were not statistically significantly different in any of the four subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses found no overall significant difference between the observed and expected numbers of deaths for accidental deaths (SMR=1.14), suicides (SMR=0.70), deaths due to malignant neoplasm (SMR=0.87), or deaths due to circulatory diseases (SMR=1.05). However, there was a significant excess of deaths due to circulatory system diseases among nonflying enlisted personnel (SMR=1.60, 95% CI 1.05-2.35, p=0.03). This increase was noted in the last report. The number of such deaths has increased from 22 to 24 and the SMR has increased slightly from 1.57 to 1.60 since the last report. By contrast, the 3 deaths of flying enlisted personnel were significantly less than the 8.6 deaths expected (SMR=0.35, CI 0.09-0.95, p=0.04).

There was a significant excess of Ranch Hand deaths caused by diseases of the digestive system (SMR=2.07, 95% CI 1.01-3.79, p=0.05). This excess was also noted in the last two reports and the number of such deaths has remained at nine since 1989. There was also a borderline significant excess of such deaths among Ranch Hand flying officers (SMR=2.79, 95% CI 0.89-6.74, p=0.07), although the number of deaths in this stratum was small (n=4).

There was a significant excess of flying enlisted Ranch Hand deaths due to ill-defined or unknown causes (SMR=6.11, 95% CI 1.02-20.17, p=0.05), although the number of deaths in this stratum was small (n=2). There was no significant excess of deaths in this category among all Ranch Hands (SMR=2.02, 95% CI 0.51-5.50, p=0.25).

The 26 Ranch Hand deaths due to malignant neoplasm did not appear to aggregate in an unusual pattern relative to that expected. The adjusted SMR for deaths due to malignant neoplasm was less than 1.0. Even so, the morphologic subcategory of malignancies called epithelial neoplasms accounted for 11 Ranch Hand deaths compared to the 8.8 expected deaths. However, this excess was not significant (SMR=1.27, 95% CI 0.67-2.20, p=0.42).

Analysis of survival status versus current dioxin levels found no significant difference between mean dioxin levels among the 968 living and 20 dead Ranch Hands with dioxin results. Survival time was also not significantly associated with dioxin levels in Ranch Hands.

In summary, the total all-cause mortality experience of the Ranch Hands was not significantly different from that expected based on the mortality experience of the Comparison population. As of 31 December 1992, 111 (8.8%) of the 1261 Ranch Hands have died; the expected number of deaths is 111.47. The overall observed and expected numbers of deaths were not significantly different for accidental deaths, suicides and deaths caused by malignant neoplasms and circulatory system diseases. However, significantly increased numbers of Ranch Hand deaths due to digestive diseases and, in nonflying enlisted personnel, circulatory system diseases continued to be seen. Among Ranch Hand enlisted flyers increased deaths due to ill-defined or unknown causes continued to be seen as well. These increases have been noted in previous reports and are, as yet, unexplained.

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